Real time scatterometry: a new metrology for in situ microelectronics process control

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Real time scatterometry: a new metrology to *in situ* microelectronics processes control

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In situ and real time control of the different process steps in semiconductor device manufacturing becomes a critical challenge, especially for the lithography and plasma etching processes. Real time scatterometry is among the few solutions able to meet the requirement for in line monitoring. In this paper we demonstrate that real time scatterometry can be used as a real time monitoring technique during the resist trimming process. For validation purposes the real time scatterometry measurements are compared with 3D Atomic Force Microscopy measurements made in the same process conditions. The agreement between both is excellent.

Introduction

During the micro and nanofabrication processes more particularly lithography or plasma etching, the CD (Critical Dimension) metrology is a key point to reach the required performance of the fabricated devices. In line process control requires real time, non destructive and non-invasive monitoring techniques. The conventional CD metrology technique such as AFM (Atomic Force Microscopy) and the CD-SEM (Scanning Electron Microscopy) are not suited for real time and run to run monitoring, because they are either time consuming or destructive and al most impossible to be used *in situ.*

Optical measurements[1] are among the few solutions able to meet the requirements for in line monitoring because they are nondestructive and potentially fast. Scatterometry belongs to the family of the optical methods. It uses the analysis of the signature of the light scattered by a periodic structure to infer the shape of a feature. Specular spectroscopic scatterometry can make use of existing spectroscopic ellipsometers[2] or reflectometers[3], and can be easily installed *in situ*[4].

In this paper we show that the scatterometry can be used for real time monitoring during the resist trimming process of a 248nm photo-resist in Ar/O_2 chemistries. Finally we prove that dynamic scatterometry provides reliable and repeatable results and shows a great potential as a real time monitoring technique for etch process.

Experimental

Experiments are carried out in an inductively coupled industrial plasma source (Decoupled Plasma Source (DPS) from Applied Materials Inc) accepting 200 mm diameter wafers. The experimental set up has been described in detail elsewhere[5]. The material investigated in this study is a commercial 248nm photo-resist M78Y resist from JSR deposited on top of a 1.5nm layer of silicon dioxide grown on a silicon substrate. It was exposed to a 248 nm wavelength using an ASML /300 exposure tool. The test pattern is a grating of equal line and space 250/250nm. The test structure area is 10x10mm. The resist pattern is exposed to plasma treatments using Ar/O2 chemistries. The plasma condition used to trim the resist in this study is Ar/O_2 (70:30 sccm), the power source is fixed at 500 W, the pressure is fixed at 4 mTorr and the substrate polarization is fixed to 0 W bias.

We used a *in situ* spectroscopic phase-modulated multi-wavelength ellipsometer UVISEL MWL-16 from Horiba JOBIN YVON (France), to characterize the patterned feature. The ellipsometer is plugged onto the DPS process chamber. The high acquisition rate of the ellipsometer allows sampling 16 different wavelengths with a 0.5s time resolution. That makes it fully compatible for *in situ* and real time control of resist trimming process which typically last several tens of seconds.

For validation purposes, the approximately 80s process has been divided in four different time intervals (20s, 40s, 60s, 80s). For each process condition, we took four strictly identical wafers. The three first wafers were trimmed at different times (20s, 40s, and 60s). The fourth wafer is trimmed until the end of the process. Before the process 3D- AFM[6] was used to measure the initial pattern shape. On the test wafers, the initial feature profiles were found to be identical to a few nanometers. We used the real time scatterometry to measure the trimmed feature profile during the etch step. After each experiment, the scatterometry measurements were compared with the 3D AFM.

Results and discussion

A comparison between real time scatterometry profile shape (CD, Height), and the 3D AFM measurements are reported in fig 1 (a, b). The reconstructed profiles, extracted using the real time scatterometry are compared to 3D AFM profiles measured on separate wafers etched during the same time. Overall, the agreement between AFM and scatterometry is very good since the difference in width and height between each other is always less than 1%. We just want to emphasize that scatterometry is reliable technique that is able to control a fast resist trimming process in real time

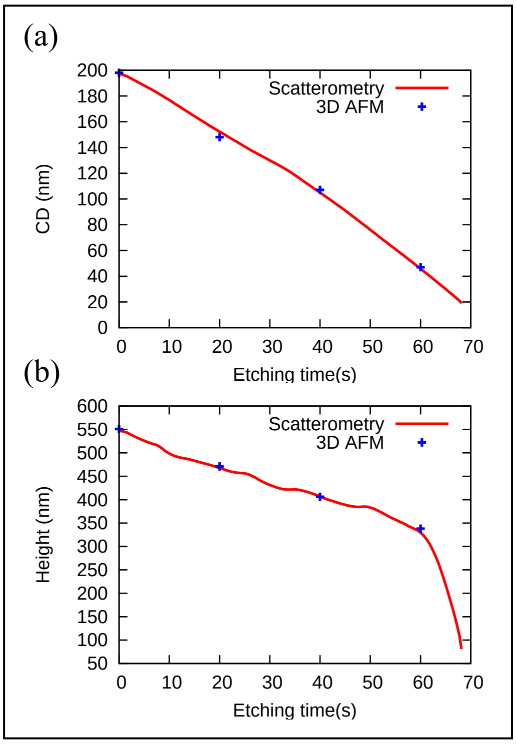

Figure 1. Real time measurement results (red line) (a) CD and (b) Height of resist feature us the processing time in Ar plasma. 3D AFM data (blue points) are shown for reference.

Conclusions

In this article we used the *in situ* real time scatterometry metrology to monitor the resist trimming process. We applied and validated this technique in Ar/O_2 chemistries. This study proves that real time scatterometry provides reliable results and shows a great potential as a monitoring technique for etch process control. The comparison between scatterometry measurement and 3D AFM measurement shows a good match for a variety of different pattern shape, within a few percent in size. This characterization technique can be viewed as an invaluable tool for the accurate control of the patterning of current and next generations of semiconductor devices.

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